2023 **Annual Conference & Exposition**
Baltimore Convention Center, MD | June 25 - 28, 2023

The Harbor of Engineering
Education for 130 Years

ASEE

Paper ID #38841

Team Building Games to Reinforce the Training of Chemical Engineering Students in Team Skills Based on Collaboration Leadership

Dr. Joaquin Rodriguez, University of Pittsburgh

2018+ University of Pittsburgh. Chemical and Petroleum Engineering Department. Assistant Professor. Teaching track.

1999-2018. Universidad Monteavila (Caracas, Venezuela). Founder, Academic Coordinator (1999-2004), Vice-Chancellor for Academic Affairs (2004-05), Chancellor (2005-15), President of the High Studies Center (2015-178)

1983-1998. Petroleos de Venezuea. Research Center (Caracas, Venezuela). Professional Engineer (1983-87). Project Leader (1987-92). Principal Researcher (1992-95). Specialty Products Business Leader (1995-99)

Hseen Baled
Michael McMahon

Team Building Games to Reinforce the Training of Chemical Engineering Students in Team Skills Based on Collaboration Leadership

Introduction

Team building games or activities are popular at work [1] - [3], and college [4]. Team games are creative activities that simulate team performance at relatively simple and engaging tasks but offering practice and reflections to apply to real job situations. They can be used when starting a new team project or sometimes later to address conflicts, to encourage positive attitudes, or to unveil new horizons on collaboration, or even as routine exercises to reinforce the dynamics of a team. They are intended to facilitate connectedness, improve team bonds, boost team morale, and develop communication and problem-solving skills [1]. They contribute to a work culture of motivation and collaboration, improve decision making strategies, enhance productivity, and they can be designed to foster creativity and out-of-the-box thinking [2]. It is important that they get adapted to situations where the members of the team feel comfortable playing, either in person or virtually [3]. There is abundant information on this topic as any online literature search may reveal, from books and scholarly papers to blogs, and diverse applications from kids to managers. Beyond that, there is a broad umbrella of the fast evolving "Science of Team Science" (SciTS) [5], and at the other side, the expanding field "Game-based learning" (GBL) with the use of games (digital and non-digital), particularly in engineering education [6], [7], using simplified realistic situations [8], [9] or digital simulations [10]. Some limited experience has been reported at ASEE Conferences on the intersection of team building games [11]- [21].

Though the requirement for developing teamwork skills in the engineering curriculum is well established, in view of the demands from industry, very little formal teaching is devoted to providing content on team essentials, best practices for improved performance, members' roles and behaviors, and team leadership. Instead, students are required to work in team projects through the curriculum with a very intensive experience at the capstone course, in what has been labeled as a "sink or swim" approach [22]. In our program, the formal training on teamwork rarely reaches the 10 hours (mainly concentrated in the First year), while the work on team projects extending through the sophomore, junior and senior years may reach around 1,000 hours of estimated involvement of individual students. In the First-Year program students are exposed to some lectures and practices as part of the general introductory courses to engineering and software. They are presented with some short videos and podcasts as preparation for the lectures. In the fall semester they are introduced to the tool of a "team Contract" and presented with a simplified template recommended to be used in team projects later in the career. A second lecture addresses the topic of "Social Loafing". With some cases presented in class for discussion. In the spring semester they are introduced to the topic of "Conflict resolution" and revisits the alignment of team contract with high performance teams. For these sections and the other activities in these introductory courses, students are placed in teams of 2-3 by CATME, and they get trained in the use of the resources it provides. Later in the career, some professors take the initiative of introducing or reinforcing teamwork skills with some lectures or exercises, mainly to deal with conflict resolution or skills for high performance teams. Some professors use

CATME to configure teams for their course projects and/or tracking team performance, but most professors allow for self-selection of team members and alternative students' assessments on team performance. One lecture for a 2-hour session with embedded team activities has been prepared (expanding on [23]) and used in capstone courses to recap on main teamwork skills and reinforce the importance for professional development.

A sample of student perception on teamwork skills is presented in Figure 1. The plot is the result of a recent survey with 48 students attending the capstone course. They were asked to highlight up to 5 of the main skills they acquired and developed during their career. Teamwork skills are shown at the very top as the most common attribute. However, it is a frequent observation by professors that students usually limit the teamwork strategy to an initial distribution of tasks (generally predetermined by the structure of the projects) and occasional meetings to assemble the contributions in reports or presentations ("divide and conquer" strategy). Experiences with senior students have proved that they rarely rely on effective planning, revisions, and updates of a general plan. Team identity is taken for granted as defined exclusively by the expectation of getting a good grade. Techniques learned in the short first-year training, like the team contract, are hardly followed. No records of progressive work are taken. Leadership is vaguely structured unless specifically requested by the assignment. Last-minute completion is generally the norm rather than the exception. Deliverables quality, sometimes outstanding, relies strongly on individual talents and exceptional efforts.
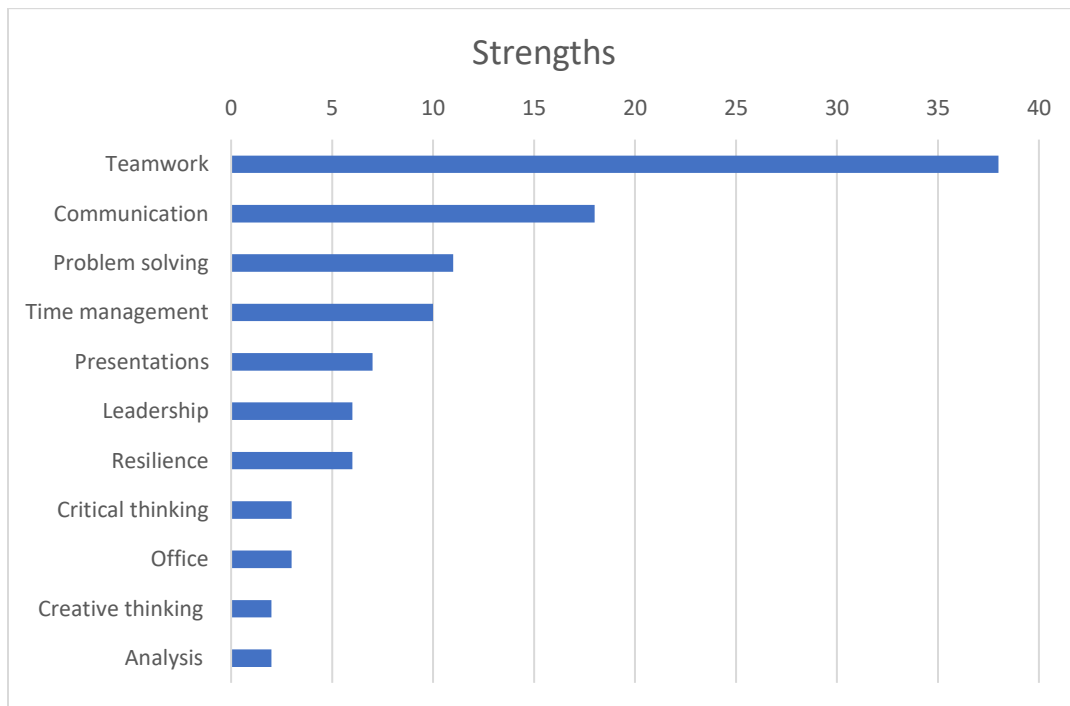

Figure 1. Survey of student perception on main skills acquired and developed during their college experience (capstone course attendants).

One proposal in place to introduce and reinforce teamwork skills through the curriculum is the use of team-building games, as referenced above. They offer a good potential for effective

learning in an engaging environment, and with the flexibility for instructors to accommodate in their courses and to adapt to specific circumstances. Two examples that have been tested are described here in detail. They were designed to reinforce team-work skills in a capstone course for chemical engineers that includes several semester-long team projects.

The Word Search game

This game has been designed for chemical engineering students, but it can be easily adapted to any other engineering or field. It is based on a word puzzle (Appendix 1) 18x18 letter boxes with 18 words referring to chemical engineering in frequent use during the curriculum.

Objectives: To experience and analyze

- The importance of teamwork for improved results.
- The importance of communication in teamwork.
- The role of leadership in teamwork.

Outcomes: By the end of this exercise, the student should be able to

- assess the relevance of teamwork for effective performance.
- assess the relevance of communication and effective teamwork.
- associate leadership and effective teamwork.

Procedure

Students were distributed in six groups, each sitting at a separate table. The proctor announced the setup of the game with a presentation, introducing the 18x18 letters word search and the list of 18 chemical engineering related words. Each group was provided with a set of six identical working sheets containing the puzzle, one for every member of the group. In addition, each group was provided with a short slip describing a specific instruction to follow (Table 1). Each set (instruction slip, puzzle sheets) was handed onto each table turned over, waiting for the starting time to be announced. The proctor emphasized the importance for each group to follow the instructions given in the slip. Students were asked to record the time for the words they find in their individual working sheets at the space provided to the right of each word, following a common clock on the screen. The proctor set the clock on the screen and announced the starting time asking students to proceed. The proctor went around the tables, completing instructions for certain groups as designed (appointing the leader for team C, right after the announcement of starting time, reminding the 2 minutes period for team B) and checking on instructions to be followed. Some warnings were needed as some groups started to depart from instructions (i.e., communicating in cases that were not allowed for).

Table 1. Strategies for completing the word search by each group.

Group	Strategy
A	Every member works independently. No communication allowed
B	Group takes no more than 2 minutes to arrange for a plan. No communication after that time
C	A leader is appointed by the proctor. The leader set the strategy. Only the leader can communicate with members. No feedback or cross communication allowed among members
D	Each member starts looking for words. Once a member finds a word, announces it, records the time in the individual sheet, and the other members cross it over on their working sheets. No other communication is allowed
E	The group picks a leader. The leader organizes the decision on the strategy. Free communication is allowed among members all the time
F	The group selects as leader the person who woke up the earliest today. The leader arranges for each member (including the leader) to take an approximately equal number of words and assign those words. If a member happens to find a word not on his/her list of assigned words, announces it, records it in the individual sheet, so no need for other members to look it for. If a member gets one of his/her assigned words found by somebody else, asks any of the neighboring members to point out a word for him to look after in replacement.

The proctor stops the game at a convenient time (8-10 minutes) after realizing that most of the groups have completed the assignment. Proctor asks the students to calculate the time difference with respect to the common starting time for each word they found and report it as one decimal figure in minutes (i.e., 1,2 min) properly converting seconds to a fraction of minutes dividing by 60. Then asks each group to collect the number of non-repeated words cumulatively found at every minute (i.e., number of non-repeated words the group found by minute 1, by minute 2, etc.), the number of not found words, and the number of repeated words. The data is presented in table format and the class is open for discussion on the results around the concepts of:

- results (number of found words)
- effectiveness (number of words per time)
- goals (percentage of completed assignment)
- performance (individual and group results, effectiveness, contributions)
- communication (impact on performance)
- strategies (impact on performance)
- leadership styles (impact on performance and environment)
- coaching (advice to team F)

Finally, the proctor asks students to submit non-graded assessments on their reflections about the experience by the end of the day.

Results

In the most recent edition of a capstone lab course, two sections of 36 students each participated in this game without prior announcement on the activity and on a different day. For section 1, 31 students were distributed in five 5-member groups and one 6-member group, each in one common table. The game was stopped after 8 minutes. Students were asked to compute the results to find the number of non-repeated words identified by every minute. Calculations required to convert seconds to fractions of minutes and some mistakes were evident. The results were posted on the screen for students to reflect upon, though the proctor provided most of the analysis. Students were asked to submit their reflections in individual assignments due by the end of the day. The proctor failed in this case to recover the individual worksheets. Most of them were handed back in the next days after being requested (eight were missed). The proctor needed to follow up later with students to clarify some of the results (i.e., some students filled their individual pages with the compiled data for the whole group, the strategies free to choose were not reported, etc.). After a thorough compilation, the proctor was able to consolidate Tables 2 and 3.

Table 2. Consolidated results for team performance described by the number of non-repeated words found in the word search (Section 1)

Team	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	Not found	Repeated words
A	5	11	12	13	14	14	14	15	3	14+
B	0	4	12	16	18	18	18	18	0	29+
C	2	6	10	14	18	-	-	-	0	0
D	3	9	13	16	18	-	-	-	0	0
E	2	6	7	10	12	15	16	18	0	0
F	1	6	14	18	-	-	-	-	0	0

Table 3. Individual performance for members in Section 1 in searching for words.

Team	1	2	3	4	5	6
A	7	6	15	X	X	-
B	7	10	11	12	7	-
C	X	X	X	X	X	-
D	3	2	7	3	3	0
E	6	3	4	5	0	-
F	3	5	5	3	2	-

Table 2 shows that group A was the most effective during the first 2 minutes, identifying 11 non-repeated words, but after that time they got very slow progress, reaching 15 non-repeated words by the end of the game, with 3 non-identified words. The number of repeated words (14) displayed in Table are based on 3 students delivering back their individual worksheets, but the total number for the 5 members in the team is estimated to be over 30. Group B spent the first two minutes setting up the strategy (they claimed it took only one minute), with no words identified in the first minute, and only 4 by minute 2, but then they were fast identifying all the

words in the next 3 minutes, but as they did not provide for a sign to stop, members kept looking for words until the end of the game. Their strategy consisted of having three people responsible for a column of 6 words each and letting the other 2 members to randomly identify words. Two members responsible for one column of words were effective in completing the search by the minute 5, while the other two columns took longer. A strong penalty for this strategy was the large number of repeated words (29). Group C set up the strategy of two sub-teams, splitting half the number of words (first nine, last nine) for each, but they were telling sub-team members the words each member was finding by pointing fingers to their work sheets, though communication was not allowed, nor feedback to the leader. This departure from the instructions set the strategy for the group someway like group D. This group did not hand back individual work sheets, but only one sheet compiling time results for 12 words. This data was used to provide the best estimate reported in Table 2. Group D completed the search in less than 5 minutes after a relatively slow start. Group E set up the strategy of selecting one teammate to record the time for words found by every member and having all the other four members search randomly for words and announcing them as soon as they found one. It is like the assigned strategy for group D but taking one member out of the word search and reduced the effectiveness of the team as they completed the search close to the end of the game. Group F had a slow start while reading the instructions and picking up the leader, but then they were fast finding words, completing the job in less than 5 minutes, with the best performance.

Table 3 shows the individual performance. Members working individually (Group A) showed significant differences, from 6 to 15 words found at the same time, as corresponding to different skills. Three members of Group B were assigned the task of one specific column of 6 words; however, they extended their search to other words, resulting in repeated words, but also displaying the ability of individual members to look for words. The other two members produced repeated words, in addition. No individual data was recovered from members in Group C. Individual performance in Group D ranged from 0 to 7 words per member, with one member not able to find a word before somebody else did it. In this case, the number of words to find was increasingly constrained by the words previously found, resulting in a significant reduction in the number of words per member. Individual performance in Group E ranged 3-6 words per member with one non-contributing member as assigned for time recording. Like members in Group D, they were increasingly limited in the number of words to find, but the fact that only four members were looking for words, instead of six for Group D, increased the average number of words per member. Individual performance at team F ranged from 2-5 words per member, where members were focused on a reduced set of words to look for.

In the second session, with a different group (Section 2), 35 students were distributed in groups of six members, except one group of five. Data was properly collected this time with all students reporting back their working sheets after completing the game, as is reported in Tables 4 and 5. As depicted in Table 4, Group A was not able to find all the words by the end of the game, with many repeated words (51), though they were fast finding words in the first 2 minutes, like Group A in Section 1. Group B set up the strategy of assigning two people per every column of 6 words, and some members extended that on their own, looking for some other words not assigned to them, as there was no stop time in their strategy. In addition, the two members

working in the same column were also repeating words as there was no subdivision among them. There was a limited number of repeated words resulting from the extra search of some members. Group C set up a basic strategy, established by the assigned leader, of asking everybody to do their best looking for words, so it turned into individual performance similar to Group A, extending the search for the entire time of the game and resulting in many repeated words (61), though they completed the word search in less than 5 minutes, which was the record time for the section. Group D, with one member less than the other teams, completed the search in less than 6 minutes, with the last three words requiring one minute each to be found. Group E decided on an equal split of 3 words per member, like the strategy advised to Group F. They did a systematic job completing the task in less than 5 minutes, after a slow start to fix the strategy. Team F performed equally fast, with a slow start to realize the advised strategy; however, a couple of repeated words resulted from some members finding words other than their assignment, but already found by the members with those assigned words.

Table 4. Consolidated performance for teams by Section 2

Team	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	Not found	Repeated words
A	9	12	12	14	16	16	16	16	2	51
B	9	13	14	16	18	18	18	18	0	17
C	3	9	14	15	18	18	18	18	0	61
D	6	11	13	16	17	18	-	-	0	0
E	2	8	15	17	18	-	-	-	0	0
F	1	9	13	16	18	-	-	-	0	2

Table 5. Individual performance for members in Section 2

Team/Member	1	2	3	4	5	6
A	10	14	5	13	12	13
B	6	5	10	4	4	6
C	18	18	13	8	9	13
D	6	6	4	2	0	-
E	3	3	3	3	3	3
F	4	3	4	4	3	2

For individual performance, results ranged from 5 to 18, when no constraint in the number of words to be found (Groups A and C), with some individuals finding the 18 words in less than 5 minutes (Group C), showing the diversity of skills. Results ranged 2-6 when the number of words were restricted to a specific number of words (column, row) to look for.

Twenty-five students from Section 1 and twenty-two students from Section 2 submitted assessments on the experience. Table 6 reports the main features from their analysis. Students clearly identified the importance of communication for effective results, and the need for strategy to reach goals on time, as the top lessons. Close to that rank were the convenience for leadership (including the impact of various styles, the impact on delaying immediate results, and the benefit of elected leaders based on grounded criteria for selection) and collaborative work. Some

students also referred to the need for a balanced distribution of work, the impact of communication (or lack of) on feelings and morale, and as contributor to provide an overall understanding of the project. Only one student disapproved of the training value of this exercise.

Table 6. Student outcomes as derived from students' assessments.

Outcome	Students	
Student identified the relation between communication and effectiveness	16	13
Student identified the benefits of defining a strategy	16	11
Student identified the relevance of leadership	10	6
Student identified the benefit of collaboration in team performance	8	8
Student found the game interesting	7	7
Student projected the game experience to real life scenarios	6	2
Student differentiated leadership styles and relation to effectiveness	6	4
Student identified the benefit of electing leaders	5	4
Student identified the benefit of coaching	4	-
Student found the game to be fun	3	-
Student identified the complexities of deciding on an optimal strategy	3	1
Student identified the connection between communication and feelings (i.e., frustration)	3	2
Student identified the importance of early setting the strategy	3	2
Student identified the convenience of continuous communication	3	2
Student identified the price of setting the strategy	3	-
Student identified the value of the game for improving team performance	2	2
Student identified the benefit of communication in boosting the morale of members	2	-
Student connected strategies to outcomes	2	-
Student identified the convenience of balanced distribution of work	2	8
Student identified the importance of criteria to select the leader	1	-
Student identified the relation between communication and overall understanding	1	-
Student identified the importance of providing feedback to the leader	1	2
Student identified the convenience of delegating tasks	-	2
Student identified the importance of team structure	-	1
Student considered the exercise a waste of time as senior students should already be clear about the impact of teamwork and communication	-	1

The testimony from one student provides a good example and summary from the assessments:

"*In the Word Search Game, I was on team A, the group that was challenged to solve the word searches individually with no communication. At first, this was an exciting challenge (at least to me, because I love word searches), but in the end, we were the only group that did not find all the words, and we had 51 repeated words. Looking back, working alone often seems easy (and is some people's preference) because it doesn't involve the time and effort of collaboration. However, it is obviously not the most efficient strategy. By minute 5, we found all the words, and we were all stuck for the last three minutes. We couldn't communicate our struggles nor work together, and we didn't reach our goal.*

The other teams had very different experiences. The two most efficient teams were D and E, who could communicate their found words and communicate freely, respectively. I think it is interesting that the most efficient team (found words the fastest and had no repeats) was the team with free communication, a leader, and a strategy. This quickly assigned structure was enough to help the team be successful. It just goes to show how important it is to plan at the beginning of the semester and assign leadership roles.

Team B had an interesting situation in which they could only communicate at the beginning, then not for the rest of the time. I think this is analogous to the enthusiasm teams have at the beginning of the semester, but eventually everyone becomes busy, a team member becomes distant/distracted, and the team loses sight of their goals. Team B shows the importance of constant communication to staying on track. Team C was also less efficient than the freely communicating teams because the only communication came from the leader. This leader was unable to check in on their teammates, nor could the teammates check in on each other, and as a result they had the most repeated words of all the groups. The teammates were working on their tasks set by the leader, and they may not have been the best, but there was no opportunity for open dialogue to optimize the plan.

I think the biggest takeaway from the Word Search Game was the importance of constant, goal-oriented communication, and internal group structure. By setting clear goals and division of work, the team can complete their tasks in an efficient manner. This activity was also a good reminder of the warning signs of some typical group-organization pitfalls. Communicate, communicate, communicate!"

Analysis of results

This exercise can be completed in less than 15 minutes for the word search including the setup of teams and instructions, 5-10 additional minutes for time calculations (it can be significantly reduced if only using minutes for the unit of records) and compiling and displaying the results, and open time for discussion. It can be administered in a 50-minute class time.

The discussion of results in the classroom needs to start with clarifying the instructions for every team and pointing to relevant results, which requires the instructor to explicitly explain the constraints and the impact on results. The instructor needs to balance the advantages and disadvantages of an open or guided discussion. It is extremely important to provide students with the time and opportunity to develop their personal reflections upon the experience and discussion, in an assignment that could be graded to motivate their completion.

This exercise, based on a simple task of searching words in a word puzzle, provided a clear illustration of differences in skills by individuals (see Group A in Section1, and Group C in section 2). It even makes the case for individuals that can complete the team assignment on their own (see member 1 and 2 on Group C at Section 2). However, differences in skill do not override the dominant impacts of communication, strategy, leadership, and workload distribution (see Groups B and D for section 1).

This exercise demonstrated that a lack of communication yielded the least effective results (see Group A for both sections). Teamwork based on purely independent contributions may start with a clear advantage derived from immediate results in comparison with the delay in other groups that spend time setting up a strategy, selecting a leader, and agreeing on terms. However, they find it more difficult to progress later due to lack of mutual support, division of workload, and track on performance. They may end up not reaching the goals in a given time frame. It also demonstrated that reducing communication in time (see Group B in section 1) or in persons (see Group C in section 2) significantly reduces the effectiveness of the team.

This exercise demonstrated that an early definition and agreement on the strategy may delay early results, but it yields faster performance later and better probability to reach goals on time (see Group B in section2).

This exercise also demonstrated that relying only on a reduced number of members (see Groups C and E in section 1) leaving other members to complete auxiliary or poorly defined tasks, reduces the effectiveness and performance of the team.

This exercise points to the advantages of selecting a leader, agreeing early on a strategy, providing for a balanced workload, keeping a continuous and open communication, and getting advice from coaching (see Groups F in both sections) leading to better results.

Name Cards game

This game has been designed to train students in organization, communication, leadership and a "culture of giving". It only requires blank note cards (2 per participant)

Objectives:

- To analyze the importance of organization, structure, and communication in teamwork
- To analyze the role of leadership in teamwork
- To develop a "culture of giving" in teamwork

Outcomes:

- By the end of this exercise the student should be able to categorize organized and non-organized structures in teamwork environments
- By the end of this exercise the student should be able to associate leadership and effective teamwork
- By the end of this exercise the student should be able to generate steps to enrich teamwork with an attitude of generosity

Procedure

Participants sit in individual places in a classroom. It may be convenient to display a common clock as the time for activities is going to be recorded by participants.

The proctor distributes blank cards, two per participant, and asks everyone to write their names/last names in front both cards, and mark one card with number "1" at top right, and the

other with number "2". They will be referred to as "card 1" and "card 2", respectively (Figure 2). The back of card 1 is going to be used to record the initial and final time for each of six experiences in the game (Figure 3), with the column "Me" to record the time difference for the participant, while the column "Group" will be completed with the time difference for the entire group. The back of card 2 is intentionally left blank.
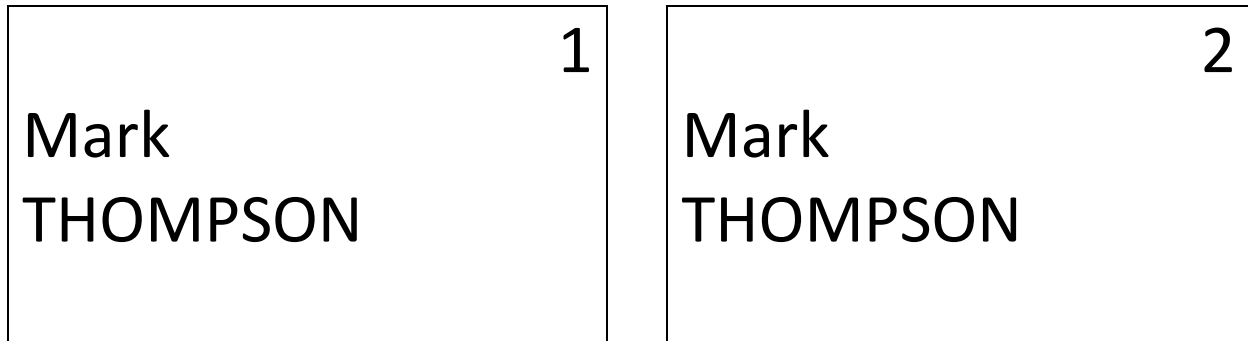
Mark THOMPSON	1

Mark THOMPSON	2

Figure 2. Example of note cards used in the Name Cards game.

Mark THOMPSON	1

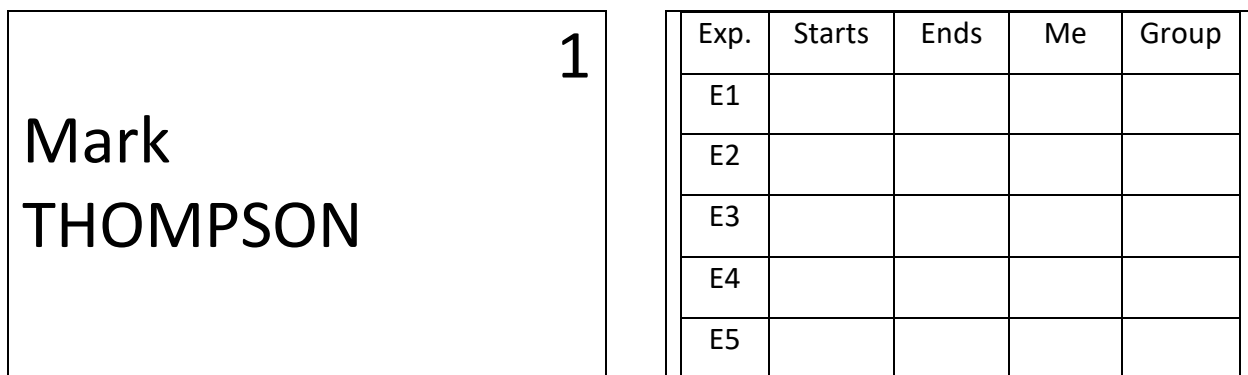| Exp.	Starts	Ends	Me	Group
E1				
E2				
E3				
E4				
E5				

Figure 3. Example of Card 1 (front and back) used in the Name Cards game.

Experience 1. The proctor collects all cards 1, shuffles them in four equally sized decks, and puts the decks in four nearby places (tables) at the front of the classroom (Note. The decision on the number of decks should be adapted to the number of participants, the time available for the game, and the structure of the space). The proctor then asks participants to recover their cards, with no communication among themselves, return to their places, and annotate the time (mm:ss) in the back of card 1 in the row headed "E1" for start and end, and the difference at column "Me". The proctor records the time difference for the last participant to get back on place and announces it to be annotated in the column "Group".

Experience 2. The proctor collects again all cards 1, shuffles them in four equally sized decks, and puts the decks in the same four nearby places (tables) at the front of the classroom. The proctor asks participants to recover their cards, allowing now for communication (i.e., giving the card to someone they know, pointing at the deck where they saw the card of someone they know, etc.), return to their places, and annotate the time (mm:ss) in the back of card 1 in the row headed

"E2". The proctor records the time difference for the last participant to get back on place and announces it to be annotated in the column "Group".

Experience 3. The proctor collects again all cards 1, and orders them in four equal size decks arranged by last name initial letter and put the decks in the same four nearby places (tables) at the front of the class, announcing the order of the letters (i.e., "deck 1, letters A to D"). The proctor asks participants to recover their cards, allowing for communications (i.e., giving the card to someone they know, asking for their names, etc.), return to their places, and annotate the time (mm:ss) in the back of card 1 in the row headed "E3". The proctor records the time difference for the last participant to get back on place and announces it to be annotated in the column "Group".

Experience 4. The proctor collects again all cards 1 and asks for a volunteer to help. The proctor gives the deck of cards to the volunteer who is in charge to call the participants to come to get their cards when named. As participants return to their places, they annotate the time (mm:ss) in the back of card 1 in the row headed "E4". The proctor records the time difference for the last participant to get back on place (volunteer) and announces it to be annotated in the column "Group".

Experience 5. The proctor collects again all cards 1 and asks for another volunteer to help. The proctor gives the deck of cards to the volunteer who is in charge to call the participants who raise a hand to identify themselves and the volunteer delivers the corresponding card approaching the participant where is sitting. Participants annotate the time (mm:ss) at receiving the card in the back of card 1 in the row headed "E5". The proctor records the time difference for the volunteer to get back on place and announces it to be annotated in the column "Group".

Experience 6. The proctor asks participants to review and reflect (3-5 min) on the results in the back of card 1, particularly the differences for the "Group" time at each experience, and the differences for the "Me" time. The proctor asks then participants to write a major personal takeaway on the back of card 2. After checking that everybody wrote the statement, the proctor asks participants to raise one hand and give the card 2 to another participant with a raised hand, moving freely to reach out. The proctor instructs participants to lower their hands immediately after receiving one card and get back to their places. The proctor takes the time from when the hands were raised until the last hand is lowered.

Finally, the proctor collects all cards 1 and thanks participants. Participants are invited to reflect on the experiences and write an assessment on their learning, identifying the relevance of organization, structure, communication, leadership and generosity on work effectiveness and inclusivity.

Results

The same sections as before (but with 30 students in section 1) participated in the game (it was played before the previously reported game). A summary of the results for time records is presented in Table 7. Section 2 consistently shows longer maximum times corresponding to the larger number of participants. A comparison of experiences 1, 2, and 3 of similar structure shows

that experience 1 took the longest time, as there was no communication (though some students couldn't avoid providing some signs to help classmates finding their cards), while experience 3 resulted in the shortest time due to the organization by last name, which added an improvement in identifying the cards. A comparison of experiences 4 and 5 of similar structure shows that having the volunteer "delivering" the name cards to participants significantly reduced the time to complete the task in comparison with the volunteer asking for participants to approach him to get their cards. When comparing the two sets of experiences (1/2/3 vs 4/5), having the sequence of card returns controlled by one person significantly increased the time for the task than for the somewhat simultaneous process for the entire group getting their individual cards.

Table 7. Partial results (minimum individual time, total completion time) for the Name Cards game

Experience	Minimum individual time		Maximum individual time	
	Section 1	Section 2	Section 1	Section 2
1	00:04	00:26	00:56	01:30
2	00:03	00:13	00:47	01:09
3	00:07	00:14	00:40	00:53
4	00:05	00:24	02:10	04:27
5	00:02	00:02	01:25	02:05

Analysis of results

Contrary to the previous game (Word Search) individual performance here is not the result of personal skills but random factors (proximity to card decks, luck in finding the card or being called first). Experiences 1 and 2 show the positive impact of communication, even in a randomized structure with limited information available and constraints (i.e., dispersion and mobility in the classroom, noise, limited knowledge). Experiences 2 and 3 reveal that the identification of the structure of the situation (i.e., partial classification of cards by last names) significantly improves the performance of the team assigned to solve it. This is further illustrated by the behavior of all the participants (Figure 4), that clarifies the trends beyond singular impacts (i.e. the effect of "low performers" at later stage). Experiences 1 and 2 show a similar early development, as the information to be communicated in advantage of experience 2 is still not advanced, but after a certain point it produces a significant improvement. Experience 3 shows a consistent advantage from the start. In addition, experiences 4 and 5 (Figure 5) intend to illustrate a difference in leadership style, as the volunteer in Experience 4 acts as a leader "asking" for participants to complete a task ("authoritarian leader") in contrast with the volunteer in experience 5 who acts as a leader "helping" participants to complete the task ("service leader"). Figure 5 also illustrates the impact of the "slowest" step in the chain (participant 5) which delay carries over the lower performance for the team. Comparison of the two sets of experiences is not normalized, as there were 4 points for distribution of the cards in experiences 1, 2, and 3, and only one point for experiences 4 and 5. It can be hypothesized that having 4 volunteers in experience 5 will produce the best performance, to exemplify the importance of leadership, despite reducing the advantage of simultaneous action of participants by an imposed sequence of tasks.
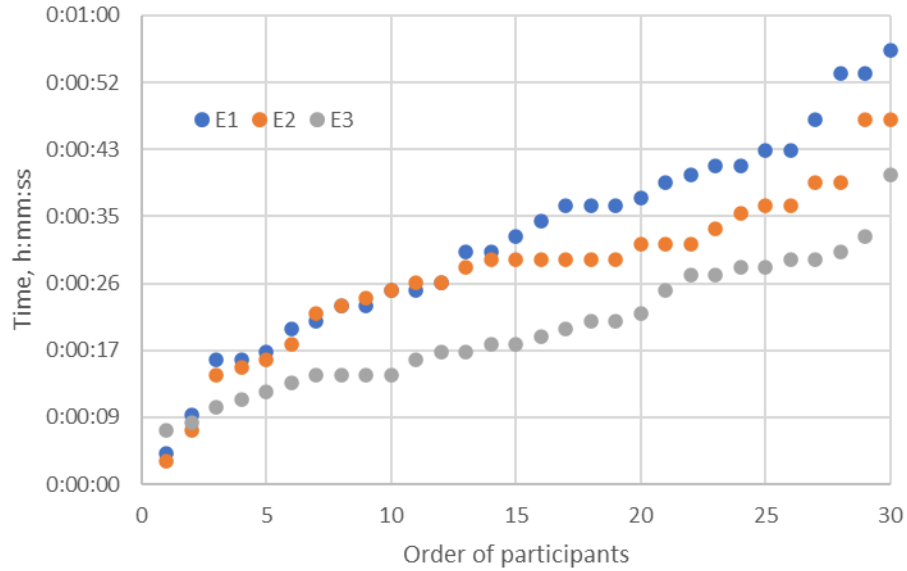
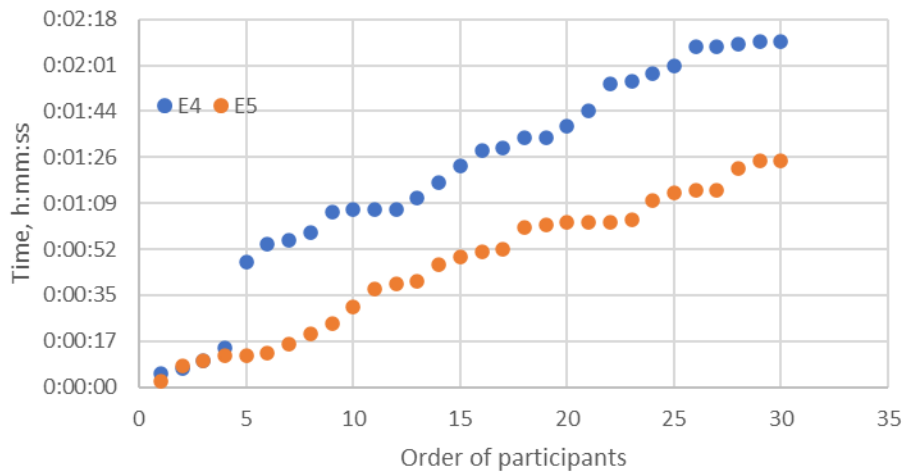Figure 4. Evolution of individual completion time for experiences 1-3

Figure 5. Evolution of individual completion time for experiences 4 and 5

Conclusions

Team-building games are at the intersection of developments in the Science of Team Science (SciTS) and Game-based learning (GBL). They offer great potential to illustrate and teach teamwork skills in engaging environments. They can be designed for specific objectives and with the flexibility to get introduced at various levels of college curriculum or professional training.

Two team-building games have been developed to reinforce teamwork skills such as organization, communication, strategy, leadership, collaboration, and workload distribution, while also evaluating differences in individual skills and the impact of random factors. These games have been tested with senior students attending a capstone course in chemical engineering. Variations and adaptations to other audiences can be easily performed, and more in-depth lessons can be extracted.

This is a fascinating and engaging area for further development. We are planning on designing more games and coordinating with faculty to avoid the repetition of games in different courses. We plan to make use of surveys and self-assessments from student's experience in teamwork to design games addressing the most critical issues (i.e., early planning has already been highlighted by students as the most common suggestion for further teamwork). Another direction for further work is the design of evaluation tools for long term impact, exploring how the experiences with team games develop into beneficial habits. We are also planning on adapting or developing specific team games for online or hybrid class settings.

References

[1] teambuilding.com https://teambuilding.com/blog/competitive-team-building-games January 25th, 2023

[2] N. Erts. Top 50 Team-Building Games that your Employees Would Love to Play. https://blog.sage.hr/top-50-team-building-games-employees-love-play/ January 25th , 2023

[3] R. Wormley. An Epic list of great team building games. WhenIWork, 2022 https://wheniwork.com/blog/team-building-games January 25th , 2023

[4] Top Hat Staff. 45+ team-Building Activities for College Students. https://tophat.com/teaching-resources/ebooks-and-guides/45-team-building-activities-for-college-courses/ January 25th, 2023

[5] K. Hall. Science of Team Science. 2019 ERC Conference, Arlington, VA https://peer.asee.org/31863

[6] J. R. Morelock, and H. M. Matusovich. All Games Are Not Created Equally: How Different Games Contribute to Learning Differently in Engineering. 2018 ASEE Annual Conference and Exposition, Salt Lake City, Utah 10.18260/1-2-29766

[7] C. A. Bodnar, D. Anastasio, J. Enszer, and D. D. Burkey. Engineers at play: Use of games as teaching tools for undergraduate engineering students. Journal of Engineering Education, 105(1), 147-200

[8] S. Alaswad, and S. Salman. Humanitarian Aid and Relief Distribution (HARD) Game. Advances in Engineering Education, 8(2), 2020

[9] M. Barger, J. Sutton, E. Roe, and R. Gilbert. The Toothpick Factory: A Simulation for The Soft Skills. 2008 Annual Conference and Exposition, Pittsburgh, Pennsylvania. 10.18260/1-2-3881

[10] J. Kittur, T. Islam. Serious Games in Engineering: The Current State, Trends, and Future. 2021 ASEE Virtual Annual Conference. https://peer.asee.org/37709

[11] M. Huyck, D. Ferguson, and R. Wasserman. Assessing Factors Contributing To Undergraduate Multidisciplinary Project Team Effectiveness. 2007 ASEE Annual Conference and Exposition, Honolulu, Hawaii. 10.18260/1-2-3016

[12] M. Y. Lanzerotti, M. Varga, S. J. Creighton, D. Langley, D. L. Cahill, and R. K. Martin. Transforming Undergraduate STEM Summer Internships in a Federal Government Institution for 21st Century Engineering Careers. 2014 ASEE Annual Conference and Exposition, Indianapolis, Indiana. 10.18260/1-2-23212

[13] N. Sambamurthy, and M. F. Cox. Developing a Behavior-Based Rubric for Assessing Professional Skills During Hiring. 2016 ASEE Annual Conference and Exposition, New Orleans, Louisiana. 10.18260/p. 27288

[14] J. Pearse. Teaching The 2 "Co's" in The Engineering Classroom. 2005 ASEE Annual Conference, Portland, Oregon. 10.18260/1-2-15373

[15] M. Dyrud. The Scavenger Hunt: A Team Building Exercise. 2008 ASEE Annual Conference and Exposition, Pittsburgh, Pennsylvania. 10.18260/1-2-3165

[16] R. Knecht. Can Peers Be Used Effectively To Assess Team: Task/Team Function Observations During Team Building Exercises. 2004 ASEE Annual Conference, Salt Lake City, Utah. 10.18260/1-2-13594

[17] C. Laramee, S. Dionne, H. Sayama, and D. Wilson. Teaching Social Complexity And Multidisciplinary Team Building: An Experimental Engineering Approach. 2009 ASEE Annual Conference and Exposition, Austin, Texas. 10.18260/1-2-5736

[18] L. Dunn, J. Matson, and K. Hunter. Impact Of A Fifty Minute Experiential Team Building Program On Design Team Performance. 2002 ASEE Annual Conference, Montreal, Canada. 10.18260/1-2-10401

[19] D. Wright, G. Hein, M. F. Desrochers, and M. Raber. Fun And Games … In The Classroom? 2003 Annual Conference, Nashville, Tennessee. 10.18260/1-2-12529

[20] G. Kiser. Applied Team Science. 2017 ERC, Arlington, VA. https://peer.asee.org/29327

[21] S. L. I. Parks. Classroom-based Games for Student Learning and Engagement. 2019 ASEE Annual Conference and Exposition, Tampa, Florida 10.18260/1-2-32510

[22] K. W. Van Treuren, and C. C. Fry. Teams and Team Building at Baylor University: Whys Should We Do This and Where Should It Occur in the Curriculum? 2017 ASEE Annual Conference and Exposition, Columbus, Ohio. 10.18260/1-2-28931

[23] R. Turton, R. Bailie, W. B. Whiting, J. A. Shaeiwitz, and D. Bhattacharyya. Analysis, Synthesis, and Design of Chemical Processes. Prentice Hall International, 2012, 4th edition. Chapter 29, pp. 929-950

Appendix 1. CHEMICAL ENGINEERING WORD PUZZLE
By Joaquin Rodriguez and Lisa Marie Huff, University of Pittsburgh

D	Y	U	S	S	E	C	O	R	P	N	B	S	S	V	R	R	W
V	X	M	V	V	N	M	D	Q	T	A	X	C	Q	V	O	E	M
E	O	A	H	C	O	E	O	E	S	S	E	N	I	N	E	A	N
N	H	S	J	L	O	P	B	D	S	T	P	R	G	M	V	C	V
E	E	S	C	J	N	N	T	L	E	I	C	F	Z	O	P	T	N
R	S	N	S	I	D	F	T	I	Q	L	G	U	E	W	K	A	I
G	K	S	R	M	F	C	R	M	T	I	N	D	G	Z	N	D	
Y	S	R	S	T	I	A	R	S	O	I	O	N	O	O	F	T	M
F	E	O	Y	E	Y	M	N	T	E	L	Z	Y	G	C	R	S	L
Z	K	T	N	M	V	X	U	Y	R	C	M	A	T	G	U	P	W
Y	G	C	C	Y	B	L	I	L	D	A	N	S	T	E	y	Y	T
Q	Q	A	V	L	N	T	T	G	A	O	N	A	W	I	F	C	K
P	E	E	D	W	W	C	N	O	B	T	M	S	L	O	O	A	B
R	Q	R	T	Q	Q	Z	R	N	P	T	I	R	F	A	K	N	S
C	X	W	V	N	G	T	Q	B	A	U	T	O	E	E	B	R	N
T	G	D	G	S	Y	S	T	E	M	S	P	F	N	H	R	T	S
X	X	A	C	T	L	V	H	M	P	E	T	B	Q	F	T	W	C
F	K	K	C	A	B	D	E	E	F	L	F	V	U	D	U	X	L

Find these words and annotate the time. Initial time: _____

BALANCES		MASS		REACTORS	
CONTROL		MODELING		SAFETY	
DESIGN		OPTIMIZATION		SIMULATION	
ENERGY		PROCESS		SYSTEMS	
FEEDBACK		PRODUCTS		THERMODYNAMICS	
HEAT		REACTANTS		TRANSFER	